said vibration direction when said AC modulation voltage is large so as to generate an inversion region in said sample.--

(Amend claim 76 as follows:)

--77. (amended) The scanning probe microscope as set forth in claim 65, wherein said integration value shows information regarding a logarithmic value of a concentration of majority carriers in equilibrium with respect to said vibration direction when said voltage is small so as not to generate an inversion region in said sample.--

A33 end

(Amend claim 77 as follows:)

--78. (amended) The scanning probe microscope as set forth in claim 65, wherein said integration shows information regarding a logarithmic value of a concentration of ionized dopants with respect to said vibration direction when said voltage is large so as to generate an inversion region in said sample.--

R E M A R K S

The specification has been amended to make editorial changes to place the application in condition for allowance at the time of the next Official Action.

Claims 1-78 were previously pending in the application. Claims 1-4, 8, 12, 36-42 and 52-54 are cancelled leaving claims 5-7, 9-11, 13-35, 43-51 and 55-78 for consideration.

Claims 1-19, 31, 32, 43, 44, 48 and 49 are rejected as anticipated by TOMITA 5,990,477. This rejection is respectfully

traversed as to claims 5-7, 9-11, 13-19, 31, 32, 43, 44, 48 and 49. Claims 1-4, 8 and 12 are cancelled.

Claim 5 recites a piezoelectric element and a detector coupled to the piezoelectric element for detecting a vibration state of the probe.

As disclosed on page 8, lines 18-25, the piezoelectric element 4 vibrates probe 3 and detector 6 detects the vibration.

In TOMITA, the quartz oscillator 4 is the vibration detector as disclosed on column 3, lines 50-51. According to claim 5, of the present invention, a quartz oscillator is not necessary.

Claim 6, 7, 9-11 and 13 depend from claim 5 and further define the invention and are also believed patentable over the cited prior art.

Claim 14 recites among other features a voltage applying unit for applying an AC voltage to a sample.

By way of example, Figure 3 in conjunction with page 7, lines 14-18 disclose an AC voltage to achieve a frequency f1 (greater than f0) is 20 Khz to 10 Mhz is applied by a voltage modulation circuit 7 to the sample 1.

TOMITA discloses two embodiments shown in Figures 1 and 5, for example. Each embodiment shows a sample 17. However, TOMITA does not disclose or suggest voltage applying unit for applying an AC voltage to the sample as recited in claim 14 of the present application. As the reference does not disclose that

which is recited, the anticipation rejection is not viable. Accordingly, reconsideration and allowance of claim 14 are respectfully requested.

Claims 15-19, 31 and 32 depend from claim 14 and further define the invention and are also believed patentable over the cited prior art.

Claims 43 and 44 also recite the voltage applying unit for applying an AC voltage to said sample. The comments above regarding claim 14 are equally applicable to claims 43 and 44.

Claims 48 and 49 depend from claim 44 and further define the invention and are also believed patentable over the cited prior art.

Claims 20-30, 33-42, 45-47 and 50-78 are rejected as unpatentable over TOMITA in view of ADDERTON et al. 6,172,506. This rejection is respectfully traversed.

Claim 14 recites in addition to a voltage applying unit, a signal detecting unit for detecting an electrical characteristic signal between the probe and the sample.

ADDERTON et al. show in Figure 1 and disclose on page 3, lines 40-45 that an oscillator 1 oscillates probe tip 3. A DC bias voltage may be applied between semiconductor sample 4 and probe tip 3 to sense charge density in sample 4 at the same frequency as the tapping of the probe against the sample surface. ADDERTON et al. neither disclose nor suggest a voltage applying unit for applying an AC voltage <u>to</u> the sample as recited in claim

14 of the present application. In addition, ADDERTON et al. do not disclose or suggest the voltage applying unit and a signal detecting unit as further recited in claim 14. As noted above, TOMITA does not disclose or suggest what is recited in claim 14. Since claims 20-30 and 33-35 depend from claim 14 and further define the invention, the combination of references would not render obvious claims 20-30 and 33-35.

Claims 43, 44 and 55 also recite a voltage applying unit for applying an AC voltage to a sample. The comments above regarding claim 14 are equally applicable to claims 43, 44 and 55. Since claims 45 through 47 and 50 through 78 depend from one of claims 43, 44 or 55 and further define the invention, the reasons set forth above regarding claims 43, 44 and 55, claims 45-47 and 50-78 are also believed patentable over the cited prior art.

In view of the present amendment and the foregoing remarks, it is believed that the present application has been placed in condition for allowance. Reconsideration and allowance are respectfully requested.

Respectfully submitted,

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<u>VERSION WITH MARKINGS TO SHOW CHANGES MADE</u>

<u>IN THE SPECIFICATION</u>:

Page 1, the paragraph, beginning on line 6, has been amended as follows:

--The present invention relates to a scanning probe microscope such as a scanning capacitance microscope ([ScaM]<u>SCaM</u>).--

Page 1, the paragraph, beginning on line 19, bridging pages 1 and 2, has been amended as follows:

--In the above-described prior art scanning probe microscope, <u>however,</u> since the coated metal of the cantilever is so thin that the coated metal has a high impedance, i.e., a low conductivity, the sensitivity of a sensor connected to the probe is substantially decreased. Also, since the coated metal of the cantilever has a larger surface to create a large stray capacitance between the cantilever and the sample, a signal generated from the probe is suppressed by the large stray capacitance. Further, since the radius of curvature of the tip portion of the probe is large, the spatial resolution cannot be increased, In order to increase the spatial resolution, the coated metal has to be made thinner to decrease the radius of curvature of the tip portion thereof; however, this further increases the impedance of the coated metal. In addition, the coated metal is easily peeled off by the friction between the coated metal and the sample. Further, Joule heat generated stays

at the tip portion of the probe to dissolve the coated metal at the tip portion of the probe. Thus, the conductivity of the coated metal is decreased.--

Page 2, the paragraph, beginning on line 9, has been amended as follows:

--Another object is to provide a scanning probe microscope capable of simply obtaining a concentration of majority carriers in equilibrium or a concentration of [departs] <u>dopants</u> in a semiconductor device.--

Page 4, the paragraph, beginning on line 26, bridging pages 4 and 5, has been amended as follows:

--In the scanning probe microscope of Figs. 1, 2A and 2B, the detector 107 detects the displacement of the conductive probe unit 103, i.e., the displacement of the cantilever 1031 by detecting light beams reflected from the cantilever 1031, so that a contact pressure of the probe 1031a to the sample 101 is detected. On the other hand, the distance in the Z-direction between the sample 101 and the probe 1031a is controlled by the piezoelectric element [101] <u>102</u>, so that the contact pressure of the probe 1031a to the sample 101 is brought close to a definite value. Additionally, information regarding a capacitance between the sample 101 and the probe 1031a is detected by the capacitance sensor 105. As a result, two-dimensional surface information of the sample 101 as well as two-dimensional capacitance information of the sample 101 can be obtained.--

Page 6, the paragraph, beginning on line 28, bridging pages 6 and 7, has been amended as follows:

--Also, a detector 6 is provided to detect the vibration state of the conductive probe 3, to generate a detection signal in response to the amplitude of the vibration of the conductive probe 3 or the difference in phase between the vibration frequency of the conductive probe 3 and the frequency f_0 of the oscillator 5. The detector 6 is preferably in proximity to the piezoelectric element 4 or within the piezoelectric element 4. In order to effectively induce a resonant state on the conductive probe 3, the mass of the conductive probe 3 is preferably equivalent to that of the piezoelectric element 4. Also, if the piezoelectric element 4 has a natural resonant frequency as in a crystal oscillator, the conductive probe 3 is vibrated at this natural resonant frequency. In this case, in order not to deteriorate the resonance characteristics of the piezoelectric element 4, the [mans] <u>mass</u> of the conductive probe 3 is preferably as small as possible. A feedback control unit 9 is provided to receive the detection signal of the detector 6 and control the location Z of the sample 1 in accordance with the output signal of the detector 6, so that the amplitude of the vibration of the conductive probe 3 or the difference in phase between the vibration frequency of the conductive probe 3 and the frequency f_0 of the oscillator 5 is brought close to a predetermined definite value. Thus, a feedback control using the

detector 6 and the feedback control unit 9 is performed upon the distance between the sample 1 and the conductive probe 3.--

Page 7, the paragraph, beginning on line 35, bridging pages 7 and 8, has been amended as follows:

--In addition, since the conductive probe 3 associated with the sharp edge 3a is made of a single material such as W, Pt/Ir Ni, Au or Ag, the sharp edge 3a is hardly peeled off from the conductive probe 3 by the friction between the sharp edge 3a and the sample 1.--

Page 10, the paragraph, beginning on line 2, has been amended as follows:

--A lock-in amplifier 14 detects a dC/dV signal from the capacitance signal C of the capacitance sensor 8A using the frequency f_1 of the AC voltage of the voltage modulation circuit 7 as a reference, while a 4μm x 4μm predetermined area of the sample 1 is scanned by the conductive probe 3 using the scan circuit 11. Thus, the dC/dV signal is stored in the memory of the computer 10 in relation to the relative location of the conductive probe 3 in the X- and Y-directions. As a result, a dC/dV image of the sample 1 is obtained by the computer 10 on a dC/dV display unit 15 as shown in Fig. 6B. In this case, if the sample 1 is a semiconductor device, the sign of the dC/dV signal indicates a polarity of [depants] dopants in a depletion region immediately below the conductive probe 3, and the absolute value

of the dC/dV signal indicates the concentration of stationary charges in the above-mentioned depletion region.--

Page 11, the paragraph, beginning on line 6, has been amended as follows:

--In Fig. 4, if the sample 1 is made of semiconductor, metal, insulator and the like, a C image displayed on the "C" display unit 13 shows the distribution of each of the semiconductor, metal, insulator and the like. Also, as stated above, a dC/dV image displayed on the dC/dV display unit 15 shows the polarity and concentration of dopants in the sample 1 which is made of monocrystalline silicon, for example. Further, a dC/dV image displayed on the dC/dX display unit 17 shows a distribution of an insulator or the like in the sample 1 which distribution is not dependent upon the dC/dV component of the capacitance between the conductive probe 3 and the sample 1. Note that, since a <u>d</u>C/dX image can be obtained without applying a voltage to the sample 1, a pn junction of a semiconductor substrate which is subject to a voltage applied thereto can be easily observed by the dC/dX image. Further, a $d^2C/dVdX$ image shows a spatial slop<u>e</u> of a concentration of dopants in the sample 1.--

Page 12, the paragraph, beginning on line 2, has been amended as follows:

--Also, in Fig. 4, the output voltage Δ of the servo circuit 9 is applied to the piezoelectric element 2 to move the

sample 1 in the Z-direction, so that the vibration amplitude of the conductive probe 3 or the difference in phase between the vibration frequency of the conductive probe 3 and the frequency f_0 of the oscillator 5 is brought close to the definite value V_{REF}. However, this feedback control operation can be carried out so that other electrical characteristic signal such as the "C" signal, the dC/dV signal, the dC/dX signal or the $d^2C/dVdX$ signal can be brought close to the [definits] definite value V_{REF}. In this case, the capacitance sensor 8A, the lock-in amplifier 14, the lock-in amplifier 16 or the lock-in amplifier 18 is connected to the servo circuit 9.--

Page 13, the paragraph, beginning on line 11, has been amended as follows:

--V_o is a voltage applied to the silicon oxide layer [7 02] 702.--

Page 15, the paragraph, beginning on line 7, has been amended as follows:

-- $=-V_s d(\ln N_A(X))/dX$ (15)--

Page 16, the paragraph, beginning on line 27, has been amended as follows:

--The current sensor [8A] 8B generates a current signal [C] I relating to a current flowing through between the conductive probe 3 and the sample 1. Thus, the current signal I is stored in the memory of the computer 10 in relation to the relative location of the conductive probe 3 in the X- and Y-

directions. As a result, the current flowing through the sample 1 using the current signal I is obtained by the computer 10 on the "I" display unit 13.--

Page 17, the paragraph, beginning on line 32, bridging pages 17 and 18, has been amended as follows:

--In Fig. 4, if the sample 1 is made of semiconductor, metal, insulator and the like, an I image displayed on the "I" display unit 13' shows the distribution of each of the semiconductor, metal, insulator and the like. Also, a dI/dV image displayed on the dI/dV display unit 15' shows the distribution of in the sample 1. Further, a dI/dX image displayed on the [dC]dI/dX display unit 17' shows boundaries of different electrical characteristics in the sample 1. Further, a $d^2I/dVdX$ image shows a spatial slope of conductivity in the sample 1.--

IN THE CLAIMS:

Claim 5 has been amended as follows:

--5. (amended) A scanning probe microscope for a sample, comprising:

a probe having a body and a sharp end, said body and said sharp end including a single conductive material; [and]

a [vibrating unit] piezoelectric element, provided at said body, for vibrating said sharp end along a direction approximately in parallel with a surface of said sample[.]; and

a detector, coupled to said piezoelectric element, for detecting a vibration state of said probe.--

Claim 9 has been amended as follows:

--9. (amended) The scanning probe microscope as set forth in claim [8]5, wherein said probe is electrically-isolated from said piezoelectric element.--

Claim 14 has been amended as follows:

--14. (amended) A scanning probe microscope for a sample, comprising:

a probe having a conductive sharp end;

a moving unit for moving said sample along a Z-direction and moving said sample in X- and Y- directions;

a vibrating unit for vibrating said probe along a direction approximately in parallel with a surface of said sample;

a vibration detecting unit for detecting a vibration state of said probe;

a signal detecting unit for detecting an electrical characteristic signal between said probe and said sample;

a control unit for controlling an interaction between said probe and said sample so that the interaction is brought close to a predetermined definite level; and

a voltage applying unit for applying an AC[/DC] voltage to said sample.--

Claim 21 has been amended as follows:

--21. (amended) The scanning probe microscope as set forth in claim 14, wherein said signal detecting unit comprises;

a detector for detecting a signal from said probe;

a diode detector, connected to said detector, for detecting an output signal of said detector; and

a frequency detector, connected to said diode detector, for detecting an output signal of said diode detector by using a frequency close to a frequency of said AC[/DC] voltage as a reference.--

Claim 22 has been amended as follows:

--22. (amended) The scanning probe microscope as set forth in claim 14, wherein said signal detecting unit comprises;

a detector for detecting a signal from said probe;

a diode detector, connected to said detector, for detecting an output signal of said detector;

a first frequency detector, connected to said diode detector, for detecting an output signal of said diode detector by using a frequency close to a frequency of said AC[/DC] voltage as a reference; and

a second frequency detector, connected to said diode detector, for detecting an output signal of said diode detector by using a frequency close to a frequency of said AC[/DC] voltage as a reference.--

Claim 24 has been amended as follows:

--24. (amended) The scanning probe microscope as set forth in claim 14, wherein said electrical characteristic signal shows a differential component of a capacitance between said

probe and said sample with respect to [an AC component of] said AC[/DC] voltage.--

Claim 26 has been amended as follows:

--26. (amended) The scanning probe microscope as set forth in claim 14, wherein said electrical characteristic signal shows a second-order differential component of a capacitance between said probe and said sample with respect to [an AC component of] said AC[/DC] voltage and a vibration coordinate of said probe.--

Claim 28 has been amended as follows:

--28. (amended) The scanning probe microscope as set forth in claim 14, wherein said electrical characteristic signal shows a differential component of a current flowing through said probe and said sample with respect to [an AC component of] said AC[/DC] voltage.--

Claim 30 has been amended as follows:

--30. (amended) The scanning probe microscope as set forth in claim 14, wherein said electrical characteristic signal shows a second-order differential component of a current flowing through said probe and said sample with respect to [an AC component of] said AC[/DC] voltage and a vibration coordinate of said probe.--

Claim 35 has been amended as follows:

--35. (amended) The scanning probe microscope as set forth in claim 14, wherein a frequency of [an AC component of]

said AC[/DC] voltage is higher than a frequency of the vibration state of said probe.--

Claim 43 has been amended as follows:

--43. (amended) A method for controlling a scanning probe microscope for a sample, comprising: a probe having a conductive sharp end; a moving unit for moving said sample along a Z-direction and moving said sample in X- and Y-directions; a vibrating unit for vibrating said probe along a direction approximately in parallel with a surface of said sample; a vibration detecting unit for detecting a vibration state of said probe; a signal detecting unit for detecting an electrical characteristic signal between said probe and said sample; a control unit for controlling an interaction between said probe and said sample so that the interaction is brought close to a predetermined definite level; and a voltage applying unit for applying an AC[/DC] voltage to said sample,

said method comprising a step of adjusting a distance between the sharp [and] end of said probe and said sample so that the detected vibration state of said probe is brought close to a predetermined definite level.--

Claim 44 has been amended as follows:

--44. (amended) A method for controlling a scanning probe microscope for a sample, comprising: a probe having a conductive sharp end; a moving unit for moving said sample along a Z-direction and moving said sample in X- and Y-directions; a

vibrating unit for vibrating said probe along a direction approximately in parallel with a surface of said sample; a vibration detecting unit for detecting a vibration state of said probe; a signal detecting unit for detecting an electrical characteristic signal between said probe and said sample; a control unit for controlling an interaction between said probe and said sample so that the interaction is brought close to a predetermined definite level; and a voltage applying unit for applying an AC[/DC] voltage to said sample,

said method comprising a step of adjusting a distance between the sharp [and] <u>end</u> of said probe and said sample so that the detected electrical characteristic signal is brought close to a predetermined definite level.--

Claim 46 has been amended as follows:

--46. (amended) The method as set forth in claim 44, further comprising the steps of:

detecting a signal from said probe by a detector;

detecting an output signal of said detector by a diode; and

detecting an output signal of said diode by using a frequency close to a frequency of [an AC component of] said AC[/DC] voltage as a reference.--

Claim 47 has been amended as follows:

--47. (amended) The method as set forth in claim 44, further comprising the steps of:

detecting a signal from said probe by a detector;

detecting an output signal of said detector by a diode; and

detecting an output signal of said diode by using a frequency close to a frequency [of an AC component] of said AC[/DC] voltage as a reference and by using a frequency close to a vibration frequency of said probe as a reference.--

Claim 50 has been amended as follows:

--50. (amended) The method as set forth in claim 43, wherein a frequency of the vibration state of said probe is lower than a frequency of [an AC component of] said AC[/DC] voltage.--

Claim 55 has been amended as follows:

--55. (amended) [The scanning probe microscope as set forth in claim 52, further comprising:]

A scanning probe microscope for a sample, comprising:

a moving unit for moving said sample in X-, Y- and Z-directions;

a conductive probe approximately perpendicular to a surface of said sample and having a sharp end capable of being in proximity to the surface of said sample;

an oscillator;

a vibrating unit, connected to said oscillator, for vibrating said conductive probe in the X-direction in accordance with a frequency of said oscillator;

a vibration detecting unit for detecting a vibration amplitude of said conductive probe to generate a vibration voltage; [and]

a feedback control unit, connected between said vibration detecting unit and said moving unit, for controlling a location of said sample in the Z-direction in accordance with the detected vibration amplitude of said vibration detecting unit, so that the vibration amplitude of said vibrating detecting unit is brought close to a predetermined definite value

an AC[/DC] voltage modulation circuit, connected to said sample, for supplying an AC[/DC] modulation voltage to said sample; and

a sensor, connected to said conductive probe, for detecting an electrical characteristic signal showing a state of said sample immediately below the sharp end of said conductive probe. --

Claim 58 has been amended as follows:

--58. (amended) The scanning probe microscope as set forth in claim 56, further comprising a second lock-in amplifier, connected to said capacitance sensor, for detecting a differential component of a capacitance signal of said capacitance sensor with respect to said AC[/DC] modulation voltage using a frequency thereof as a reference.--

Claim 59 has been amended as follows:

--59. (amended) The scanning probe microscope as set forth in claim 58, further comprising a third display unit for displaying the differential component of the capacitance signal of said capacitance sensor with respect to said AC[/DC] modulation voltage while a predetermined area of said sample in the X- and Y-directions is scanned by said conductive probe using said moving unit.--

Claim 62 has been amended as follows:

--62. (amended) The scanning probe microscope as set forth in claim 60, further comprising a fourth lock-in amplifier, connected to said third lock-in amplifier, for detecting a second-order differential component of the capacitance signal of said capacitance sensor with respect to the vibration direction of said conductive probe and said AC[/DC] voltage by said AC[/DC] modulation voltage using a frequency thereof as a reference.--

Claim 64 has been amended as follows:

--64. (amended) The scanning probe microscope as set forth in claim 56, further comprising:

a second lock-in amplifier, connected to said capacitance sensor, for detecting a first differential component of a capacitance signal of said capacitance sensor with respect to said AC[/DC] modulation voltage using a frequency thereof as a reference;

a third lock-in amplifier, connected to said capacitance sensor, for detecting a second differential component of a capacitance signal of said capacitance sensor with respect to a vibration direction of said conductive probe using a frequency of said oscillator as a reference;

a computer, connected to said first and second lock-in amplifiers, for calculating a ratio of said second differential component to said first differential component; and

a sixth display unit for displaying information relating to said ratio while a predetermined area of said sample in the X- and Y-directions is scanned by said conductive prove using said moving unit.--

Claim 65 has been amended as follows:

--65. (amended) The scanning probe microscope as set forth in claim 56, further comprising:

a second lock-in amplifier, connected to said capacitance sensor, for detecting a first differential component of a capacitance signal of said capacitance sensor with respect to said AC[/DC] modulation voltage using a frequency thereof as a reference;

a third lock-in amplifier, connected to said capacitance sensor, for detecting a second differential component of a capacitance signal of said capacitance sensor with respect to a vibration direction of said conductive probe using a frequency of said oscillator as a reference;

a computer, connected to second and third lock-in amplifiers, for calculating a ratio of said second differential component to said first differential component and calculating an integration value of said ratio in the X-direction,

a sixth display unit for displaying said integration value while a predetermined area of said sample in the X- and Y-directions is scanned by said conductive probe using said moving unit.--

Claim 68 has been amended as follows:

--68. (amended) The scanning probe microscope as set forth in claim 66, further comprising a fifth lock-in amplifier, connected to said current sensor, for detecting a differential component of a current signal of said current sensor with respect to a voltage of said AC[/DC] modulation voltage using a frequency thereof as a reference.--

Claim 69 has been amended as follows:

--69. (amended) The scanning probe microscope as set forth in claim 68, further comprising an eighth display unit for displaying the differential component of the current signal of said current sensor with respect to said AC[/DC] modulation voltage while a predetermined area of said sample in the X- and Y- directions is scanned by said conductive probe using said moving unit.--

Claim 72 has been amended as follows:

--72. (amended) The scanning probe microscope as set forth in claim 70, further comprising a seventh lock-in amplifier, connected to said sixth lock-in amplifier, for detecting a second-order differential component of the current signal of said current sensor with respect to the vibration direction of said conductive probe and said AC[/DC] voltage by a frequency of said oscillator as a reference and said AC[/DC] modulation voltage using a frequency thereof as a reference.--

Claim 74 has been amended as follows:

--74. (amended) The scanning probe microscope as set forth in claim 55, wherein a frequency of said AC[/DC] modulation voltage is higher than a frequency of the vibrating unit.--

Claim 74, second appearance, has been amended as follows:

--[74]75. (amended) The scanning probe microscope as set forth in claim 64, wherein said ratio shows information regarding a slope of a concentration of majority carriers in equilibrium with respect to said vibration direction when said AC[/DC] modulation voltage is small so as not to generate an inversion region in said sample.--

Claim 75 has been amended as follows:

--[75]76. (amended) The scanning probe microscope as set forth in claim 64, wherein said ratio shows information regarding a slope of a concentration of ionized dopants with

respect to said vibration direction when said AC[/DC] modulation voltage is large so as to generate an inversion region in said sample.--

Claim 76 has been amended as follows:

--[76]77. (amended) The scanning probe microscope as set forth in claim 65, wherein said integration value shows information regarding a logarithmic value of a concentration of majority carriers in equilibrium with respect to said vibration direction when said voltage is small so as not to generate an inversion region in said sample.--

Claim 77 has been amended as follows:

--[77]78. (amended) The scanning probe microscope as set forth in claim 65, wherein said integration shows information regarding a logarithmic value of a concentration of ionized dopants with respect to said vibration direction when said voltage is large so as to generate an inversion region in said sample.--